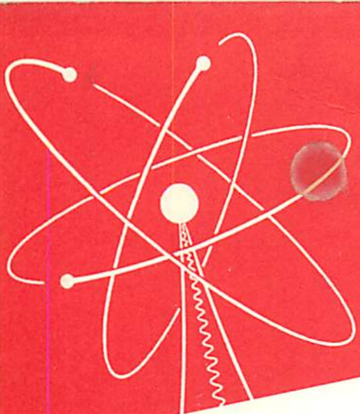


SWEEP OSCILLATORS

Lesson T2C-11A

-11

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-11A

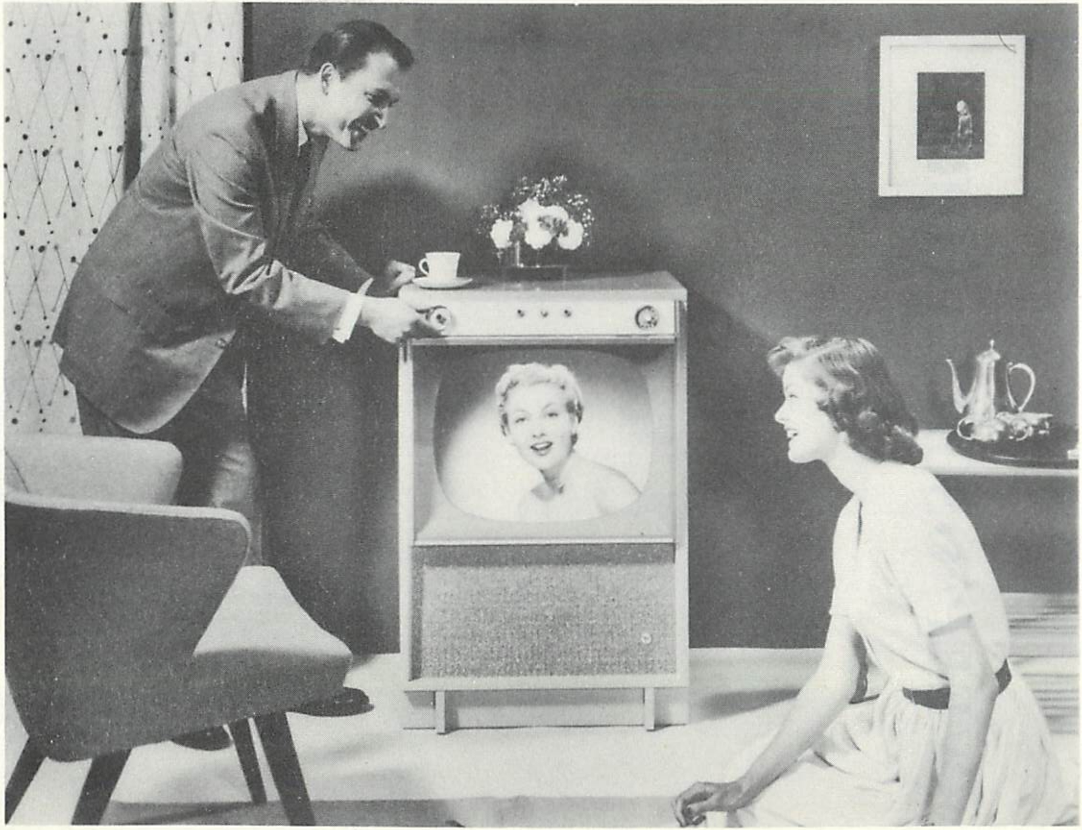
SWEEP OSCILLATORS

4141 Belmont Ave.

ELECTRONICS TELEVISION
DTI
DeVRY Technical Institute

Chicago 41, Illinois

COPYRIGHT 1956



A sloping front tuning panel for tuning comfort and a tilted screen for no-glare viewing are featured in this television console receiver, which is adaptable to either vhf or all-channel vhf-uhf reception.

Courtesy Westinghouse Electric Corp.,

SWEEP OSCILLATORS

Contents

PAGE

RC Circuits 5

The Sweep Voltage 7

Discharge Tube Action 7

The Blocking Oscillator 10

  Pulse Production 10

  Circuit Action Details 12

  Frequency Control 14

The Multivibrator 15

  The Basic Multivibrator Circuit 17

  The Cathode Coupled Multivibrator 19

  Frequency Control 20

Sine-Wave Oscillator 20

Producing Sawtooth Current 22

Sweep Oscillator Circuits 23

  Vertical Oscillators 24

  Horizontal Oscillators 29

Only by looking about us can we evaluate our situation and only by being courageous surmount the greatest obstacles.

—Kay Silver

SWEEP OSCILLATORS

In addition to the radio-frequency oscillator in the tuner, a television receiver employs two other oscillators. Called **sweep oscillators,** they generate alternating voltages of 60 and 15,750 cycles, respectively. These oscillators originate the currents carried by the vertical and horizontal deflection coils of the picture tube yoke. Since the television system uses a field rate of 60 per second, a 60 cycle per second deflection current is produced in the vertical coils by the voltage generated in the vertical sweep oscillator. With 30 frames per second and 525 lines per frame, the horizontal sweep oscillator generates a voltage with a frequency of 30 × 525 or 15,750 cycles per second and, in turn, produces a deflection current of this frequency in the horizontal coils.

As explained in an earlier lesson, the required side to side and up and down motion of the spot on the picture tube screen is obtained by means of a deflecting flux which builds up gradually and then falls quickly for each cycle. This action provides the desired even scanning motion of the spot while picture details are being produced, and then returns the spot quickly to the left side of the screen, or the top, as the case may be, to start the next line or field. To produce flux changes of this nature, the currents in the deflection coils have sawtooth wave-form. Thus, the vertical and horizontal sweep oscillators must provide output voltages with wave-forms such that they produce sawtooth currents in the coils of the yoke.

In the various types of picture tubes, the electron beam is deflected through an angle of anywhere from 50° to 90° to provide a raster which covers the entire screen area. The deflection current produces a flux of sufficient strength to cause this extent of beam deflection. To produce current of this magnitude in the deflection coils requires a higher level of voltage than is generated by the sweep oscillators. Therefore, in each complete deflection circuit, the sweep oscillator is followed by a voltage amplifier stage, the output of which produces the relatively large sawtooth current required in the deflection coils.

According to their manner of operation, television receiver sweep oscillators fall into the following three categories: (1) blocking oscillators, (2) multivibrators, (3) sine-wave oscillators. The circuit arrangement and operation of each of these is described in this lesson. The choice of the types used in the vertical and horizontal deflection circuits varies with the designer. Thus, the vertical and horizontal sweep oscillators in a given receiver may be both blocking oscillators, both multivibrators, one of each, or a blocking oscillator or multivibrator in the vertical circuit with a sine-wave horizontal oscillator. As will be explained, the relatively high stability of the sine-wave type makes it unsuited for the vertical deflection circuit.

In every case, the sweep circuit includes an RC network for the purpose of forming the desired deflection voltage. For this reason, the basic action in RC networks is reviewed here briefly before the various oscillators are described.

RC CIRCUITS

In the simple RC circuit of Figure 1A the direct voltage E of the battery is applied to resistor R and capacitor C in series when switch S is thrown to the position shown. Under these conditions, a flow of electrons in the direction of the arrows takes place until the capacitor is charged to a voltage E_c equal to E and with the polarity as indicated.

This charging action requires a period of time proportional to the resistance of R and capacitance of C, and occurs at an exponential rate such that during a time $T = RC$, the capacitor charge is increased by 63.2% of the total change that can occur. Each time constant T, in seconds, is the product of resistance R in ohms and capacitance C in farads, or R in megohms and C in microfarads.

The curve in Figure 1B shows the changes of the capacitor charging rate over a period of time equal to 5T. Here, in per cent of the applied voltage E, the capacitor voltage E_c is plotted against time in time constants.

In the television receiver, two sweep oscillators, synchronized by the received sync signals, provide the 525 line raster which is modulated in brightness to produce the picture. Courtesy Emerson Radio and Phonograph Corp.

Assuming C is discharged completely at the beginning of the action, E_c is equal to 63.2% of E one time constant after the switch is closed. At the end of two time constants, E_c is 86.5% of E, 95% after three, about 98.2% after four time constants, and 99.3% of E at the end of the fifth time constant. Thus, for practical purposes, the capacitor charges completely in a period of time equal to 5T or 5RC.

Any time after the capacitor has charged to some given voltage E_c, when the switch S of Figure 1A is thrown to the up position, the battery is disconnected and the active circuit is as shown in Figure 2A. Here, the charge E_c is the only voltage source in the circuit, and electrons flow in the direction of the arrows to leave the negative plate of C and enter the positive plate, thus discharging the capacitor.

As shown by the curve of Figure 2B, the capacitor is discharged down by 63.2% to 36.8% of its initial charge E_I, during the first time constant. During the following four time constants, E_c decreases to 13.5, 5.0, 1.8, and 0.7 per cent, respectively, of its initial charge. Therefore, the capacitor may be said to discharge completely after a period equal to 5T, or 5RC.

For the action of Figures 2A and 2B, the voltage E_I represents the charge on the capacitor plates at the instant the switch is thrown to the position shown in Figure 2A. Thus, E_I may be equal to or less than the battery voltage E, depending upon how long the switch was left in the position of Figure 1A.

For example, if switch S is set to connect the battery for a period equal to 2T, and then set to discharge the capacitor, the initial capacitor voltage E_I is equal to 86.5% of E at the beginning of the discharge action. After one time constant, the capacitor voltage will have reduced to 36.8% of 86.5% of E, or to about 31.8% of E.

To draw the complete charging curve of Figure 1B, it has been assumed that capacitor C in Figure 1A was completely discharged. However, in a practical electron circuit, a capacitor has some initial charge, and then is charged or discharged further due to a change in the applied voltage. For such cases, the curves of Figures 1B and 2B represent the way in which the capacitor voltage changes from a lower to a higher value, or from a higher to a lower voltage.

For example, when circuit conditions are such that a capacitor has a voltage E_c equal to the applied voltage E_a, neither a charge nor discharge of the capacitor takes place. However, if E_a is increased suddenly, the capacitor will begin charging toward this new higher value. The total change of capacitor voltage which can occur is the difference between the new value of E_a and the original E_c, and can be expressed as $E_a - E_c$. If the difference between E_a and E_c is E, then the curve of Figure 1B shows how the capacitor voltage E_c increases during a period of five time constants after the sudden increase of E_a.

On the other hand, if with E_c equal to an applied voltage E_a as above, E_a is reduced suddenly, the capacitor will begin discharging toward this lower value. The total change of capacitor voltage which can occur is the difference between the original capacitor voltage E_c and the new applied voltage E_a, expressed as $E_c - E_a$. When the RC circuit is shorted as in Figure 2A, the curve of Figure 2B shows how E_c reduces to zero.

If $E_c - E_a = E_I$ (the total change which can occur), then the curve shows how the capacitor voltage E_c decreases during a period of "5 time constants" after the sudden decrease of E_a.

THE SWEEP VOLTAGE

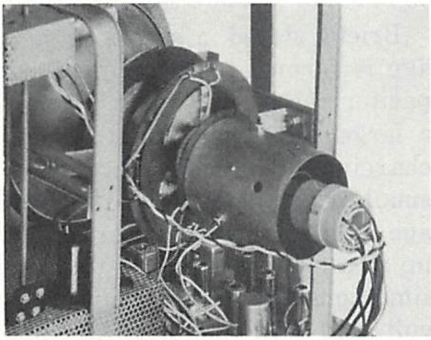
The deflection circuit amplifier stage, together with the deflection coils, present both resistance and inductance to the sweep voltage generator. Due to the resistance component of this load circuit, the generated sweep voltage must contain a sawtooth component, since a resistive circuit carries current with the same wave-form as the applied voltage. Due to the inductance of the deflection coils, the sweep voltage must contain a rectangular or pulse component also. The production of the combination sawtooth-rectangular sweep voltage wave-form is explained later in this lesson, and the following paragraphs concern only the method of forming the sawtooth component.

DISCHARGE TUBE ACTION

Briefly stated, a sawtooth voltage is formed by charging a capacitor relatively slowly through a large resistance, and then discharging it quickly through a small resistance. Thus, the voltage across the capacitor builds up at a slow rate due to the long time constant of the charge circuit, and then falls at a fast rate due to the short time constant of the discharge circuit. If the time of charge were several time constants long, the capacitor voltage wave-form would have considerable curvature as shown by the charge curve in Figure 1B.

However, as minimum curvature of the sawtooth wave is desired, R and C values are selected such that the time constant of the charge circuit is much longer than the interval during which the capacitor is allowed to charge. For example, in Figure 1, if the capacitor is permitted to charge to only 20% of E, the time required is only about one-sixth of one time constant. As the charge curve is nearly straight in this region, a resulting sawtooth wave is produced with only slight curvature.

A sawtooth voltage can be produced by the circuit of Figure 3. Here, a direct voltage is applied to resistor R_1 and capacitor C_1 in series. The negative terminal of the voltage source connects to ground. Switch S_1, connected across the capacitor, is alternately opened and closed, as shown in Figures 3A and 3B, respectively.



A color television receiver employs this large deflection yoke. However, the deflection currents are produced by sweep circuits like those used in the black and white receivers.
Courtesy Admiral Corp.

With S_1 open, the only path for electrons is from ground to the lower plate of C_1, and from the upper plate, through R_1 to the positive terminal of the voltage source. This electron flow charges C_1 to the polarity indicated. The charging action produces a voltage across C_1, and this voltage forms the output, E_0, of the circuit. With S_1 open, E_0 rises as shown between points 1 and 2 in Figure 3C.

Then, when the switch is closed momentarily, it shorts the terminals of the capacitor, as shown in Figure 3B. Electrons flow from the negative plate of C_1 through S_1 to the positive plate, discharging the capacitor, as indicated by the large arrows in the Figure. Small arrows indicate that there is current also from ground through S_1 and R_1 to the source positive terminal. Since the resistance offered by S_1 is much lower than R_1, the capacitor discharges in a much shorter time than it took to charge. This rapid fall of capacitor voltage is indicated by the E_0 curve between points 2 and 3 in Figure 3C.

At point 3, the switch is opened to allow C_1 to charge again, and at point 4, S_1 is closed to discharge the capacitor, and so on. Thus, by opening and closing the switch at suitable intervals, a continuous succession of sawtooth voltage waves are produced across C_1 as long as the action is desired. During the relatively long charge time, the time constant is equal to R_1C_1. During the short discharge time, the time constant is R_sC_1, where R_s is the low resistance of the switch.

Although the circuit of Figure 3 illustrates the basic sawtooth forming action, an automatic switching arrangement is needed for practical applications. In television sweep circuits, an electron tube performs the function of switch S_1. The capacitor charges through a resistor, but discharges through the tube. Because its purpose is to discharge the sawtooth forming capacitor at the desired intervals, the tube is called a **discharge tube.**

Figure 4 shows an RC sawtooth forming circuit, with discharge tube V_1 connected across capacitor C_1, thus replacing switch S_1 of Figure 3. In the circuit of Figure 4, tube V_1 is operated in such manner that it is cut off for relatively long periods, in between which it conducts for short intervals. A controlling voltage E_I, with the pulse wave-form indicated, is applied to the grid. The negative portions of E_I hold the tube cut off, while the short duration positive pulses cause it to conduct plate current briefly. When V_1 is cut off, circuit conditions here are the same as in Figure 3A. That is, the nonconductive tube is like an open switch. C_1 is charged by electron flow from ground to its lower plate, and from its upper plate, through R_1 to B+.

When a positive pulse of E_I arrives, it swings the grid of V_I positive, thus driving the tube out of cutoff. When conductive, the tube has much lower resistance than R_1 and therefore corresponds to the closed switch of Figure 3B. Thus, as E_I causes V_1 to conduct momentarily, the tube shorts the terminals of capacitor C_1. Electrons flow from the negative plate of C_1 to the cathode of V_1, and through the tube to the positive plate of C_1. This electron flow discharges the capacitor. At the end of the positive pulse, E_I again drives the discharge tube to cutoff, and C_1 begins charging to produce the next sawtooth cycle.

The way in which the input pulse voltage E_I determines the timing of the produced sawtooth voltage E_0 is shown in Figure 5. When E_I is negative, E_0 rises in the positive direction due to the charging action of the capacitor when the tube is cut off. When E_I is positive, the conducting tube discharges the capacitor to make E_0 fall quickly to zero. As shown by the dashed lines drawn from curve A to curve B, the periods during which E_I is negative determine the E_0 rise time, while the positive pulses of E_I determine the interval during which E_0 falls. One complete sawtooth cycle is produced by each cycle of the pulse voltage E_I.

Although the pulse voltage wave-form E_I of Figure 5A resembles the sync pulse signal obtained from the composite video wave, the sync pulses are not suitable to drive the discharge tubes of the sawtooth forming circuits. One reason is that the sync pulses are much shorter in duration than the time required to complete the respective vertical and horizontal return sweep motions of the picture tube beam. Another is that it is desirable to produce a raster on the screen regardless of whether a signal is being received. Since the sync signals are generated at the television transmitting station, if no station were tuned in, there would be no deflection voltages produced, and the spot would remain stationary with consequent damage to the center of the screen.

Therefore, the television receiver generates a pulse voltage like that of Figure 5A in each of the two deflection circuits. A **pulse generator** produces 60 cps pulses to drive the discharge tube in the vertical deflection circuit, while a second pulse generator produces 15,750 cps pulses in the horizontal deflection circuit. The pulse generators are timed by the respective vertical and horizontal sync pulses obtained from the output of the sync circuits.

The pulse generator usually forms a portion of the sweep oscillator. The complete sweep oscillator includes the pulse generator, discharge tube, and sawtooth forming RC circuit. However, there are a number of variations in arrangement. In some cases, a single tube serves as pulse generator and discharge tube. In others, separate tubes are used. In the multivibrator type, the pulse generator requires two tubes, but one doubles as the discharge tube. The sweep oscillators are named according to the type of pulse generator employed. Thus, the following paragraphs describe the circuit operation of the three basic types of pulse generators used in television receiver sweep circuits.

THE BLOCKING OSCILLATOR

In the schematic diagram of the **blocking oscillator** shown in Figure 6A, transformer primary L_1 is in series with the plate of tube V_1, while capacitor C_1 and resistor R_1 are in series across transformer secondary L_2. One end of R_1 and L_2 and the tube cathode are grounded, while the tube grid connects to point X, the junction between C_1 and R_1.

Pulse Production

When the plate voltage supply circuit is closed, an initial surge of tube plate current occurs in transformer primary L_1. Due to their inductive coupling, this surge of primary current induces a voltage in the secondary L_2. Impressed across C_1 and R_1 in series, the secondary voltage charges capacitor C_1. Due to the charging current, the voltage across R_1 drives the grid of V_1 positive with respect to the cathode.

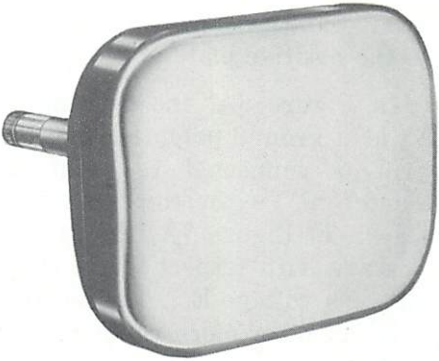
The positive grid voltage causes a further increase of plate current and the action continues to the point of plate current saturation. Since no further increase of plate current is possible, the induced secondary voltage dies out and capacitor C_1 begins to discharge through R_1 and L_2. Since the discharge current is opposite in direction to the charging current, the polarity of the voltage across R_1 is reversed so that the grid is driven negative.

This grid voltage change reduces the plate current which induces a comparatively high voltage surge in secondary L_2. This voltage polarity is opposite that induced by an increase of plate current, therefore the resulting current in R_1 produces a voltage which drives the grid negative beyond plate current cutoff.

With zero plate current, the induced voltage across L_2 dies out, and the capacitor continues to discharge. However, as C_1 discharges, the discharge current decreases gradually, and the negative voltage on the grid is reduced until the tube becomes conductive again, the plate current increases, and the entire cycle repeats.

In Figure 6B, the curve indicates the voltage wave-form at the grid of tube V_1 in Figure 6A due to the action described. This wave-form is the voltage across resistor R_1 produced by alternate charging and discharging of capacitor C_1. Thus, by employing the grid and cathode as output terminals, the blocking oscillator output provides the voltage pulse indicated.

Although the negative portion of this voltage wave is not rectangular like that of Figure 5A, it serves the desired purpose. Both wave-forms have negative portions which are long in duration compared with their positive portions. Therefore, they are capable of holding the discharge tube cut off for a much longer time than they permit it to conduct.



Generated by the deflection circuits, sawtooth currents in the picture tube yoke produce the varying magnetic fields which sweep the scanning beam to form the required pattern of lines on the screen.

Courtesy Raytheon Mfg. Co.

Circuit Action Details

To follow the blocking oscillator action closely, the tube and transformer primary of Figure 6A have been removed to provide the simplified schematic of Figure 7A. When the plate current is increasing, the expanding lines of the magnetic field around the primary induce a voltage in the secondary, and the polarities of the voltage across L_2, C_1, and R_1 are as indicated. At point X, no difference of potential exists between the capacitor and resistor. The plus and minus signs indicate that point X is positive with respect to ground and negative with respect to the positive plate of C_1.

In Figure 6A, the cathode of V_1 is at ground potential, and the grid is connected to point X. Therefore, with the polarities shown in Figure 7A, the grid is positive with respect to the cathode by a voltage E_{R_1}. The positive grid causes a more rapid rise of plate current thereby inducing a greater voltage E_{L_2}, which in turn increases the current in the circuit and produces a still higher grid voltage E_{R_1}. This cumulative action drives the grid of V_1 to a positive voltage which causes plate current saturation.

During the period the grid is positive, a cathode to grid electron flow takes place so that capacitor C_1 actually charges through both V_1 and R_1 as shown in Figure 7B. The arrows indicate the direction of electron flow, and the combination of V_1 and R_1 in parallel is in series with C_1.

In fact, with the grid positive, the grid-cathode resistance R_{gk} is so low compared to R_1 that practically all of the electron flow is through the tube rather than through R_1. Thus, the time constant of the charging circuit is determined by the values of R_{gk} and C_1.

To provide a close comparison between grid voltage and plate current, in Figure 8 a slightly modified copy of the curve of Figure 6B is drawn below the I_b-E_c characteristic curve of tube V_1, and various points are numbered in time-sequence for one complete cycle. The vertical dashed line indicates the positive grid voltage at which plate saturation occurs.

As described so far, the positive swing of grid voltage is shown between points 1 and 2 on the E_c curve of Figure 8. As capacitor C_1 continues to charge, the charging current dies down thereby reducing the voltage across R_1 and R_{gk}. Since this voltage constitutes the grid voltage for tube V_1, it is shown by the declining curve between points 2 and 3. After the decreasing grid voltage reaches the saturation point "m" on the I_b-E_c curve, a further decrease of E_c results in a decrease of plate current.

The decreasing plate current causes a collapse of the magnetic field around coil L_1, Figure 6A, so that the lines of force again cut the turns of L_2. Under these conditions a voltage of E_{L_2} is induced in L_2, and has the polarity indicated in Figure 9A. Capacitor C_1 has been charged to E_{C_1} and thus, for an instant, the circuit contains two sources of emf, E_{L_2}' and E_{C_1}.

In Figure 9B, this circuit has been rearranged to show more clearly that the two voltages E_{L_2}' and E_{C_1} are series aiding and applied across R_1. The voltage E_{R_1} is now equal to E_{L_2}' plus E_{C_1}. Also, point X is negative with respect to ground, and since the grid voltage is equal to E_{R_1}, the grid of the tube instantly becomes highly negative. This polarity reversal of grid voltage is shown between points 3 and 4, Figure 8.

During this negative swing, as soon as E_c reaches cutoff, the plate current is reduced to zero, thereby causing a rapid collapse of the L_1 magnetic field and a large induced voltage E_{L_2}'. This voltage added to E_{C_1} results in a momentary overshoot of negative grid voltage, which quickly decreases to the value indicated at point 5.

With the grid of the tube driven negative beyond cutoff, there is no plate current in transformer primary L_1, and no induced voltage in secondary L_2. Under these conditions, with no other source of voltage in the circuit of Figure 9B, capacitor C_1 discharges through resistor R_1 and the d-c resistance of coil L_2, which is shown as R_{L_2} in the rearranged circuit of Figure 9C.

During this portion of the cycle, point X is negative with respect to ground, therefore, the grid-cathode resistance of the tube is so high that its shunting effect across R_1 is negligible. Also, the resistance of coil L_2 is low compared to that of R_1 so that the discharge rate depends upon the time constant R_1C_1. Thus, as indicated on the E_c curve of Figure 8, the discharge rate, shown between points 5 and 6, is of longer duration than the charge rate shown between points 2 and 3.

Starting at point 5, the drop across resistor R_1 is equal to the capacitor voltage E_{C_1}. As the discharge continues, the displacement current becomes smaller and the drop across R_1 reduces until, at point 6, it is equal to the tube cutoff E_{co}. Finally, at the instant E_{R_1} becomes less than E_{co}, plate current is re-established and the cycle repeats.

The interval between points 5 and 6 represents the time taken for C_1 to discharge through R_1 sufficiently to allow another cycle to begin, and it depends upon the time constant R_1C_1. Therefore, varying either of these components results in a change of oscillation frequency.

Frequency Control

In a blocking oscillator circuit, the frequency of oscillation depends upon the grid circuit resistor and capacitor, as mentioned, and upon the electric properties of the transformer. In the circuit of Figure 6A for example, either R_1 or C_1 may be made variable to permit manual adjustment of frequency. Also, sync pulses may be applied to the grid of the blocking oscillator tube to cause the circuit to oscillate in exact synchronism with the incoming pulses. The sync pulses, are applied with positive polarity to initiate conduction of the tube shortly before conduction would start due to the natural or free-running action of the circuit.

With a shelf to hold an ornament such as the planter shown, this receiver forms a very attractive part of the home furnishings.
Courtesy Bendix Radio—
Div. of Bendix Aviation Corp.

To show the triggering action of the sync pulses, several cycles of the blocking oscillator grid voltage wave-form are drawn in Figure 10A. Here, the solid-line curve indicates the actual grid voltage variations as controlled by the sync pulses, while the dashed-line curves indicate that each cycle would begin somewhat later if the oscillator were allowed to operate at its free-running frequency.

At the natural or free-running frequency, each cycle would occupy a time interval T_N, but at the controlled frequency, each cycle actually occupies a shorter interval T_s as indicated. T_s is the period from the beginning of one sync pulse to the beginning of the next.

When a positive sync pulse is impressed on the grid at an instant when the negative bias is only slightly greater than plate current cutoff, the positive pulse reduces the grid voltage to less than cutoff, and thus initiates a cycle of oscillation. Referring to Figure 10A, the sync pulses occur just before the grid voltage curve crosses the cutoff (co) axis.

If the free-running frequency of the oscillator is higher than that of the sync pulses, then T_N will be shorter than T_s. The curve of Figure 10B illustrates this condition. Here, sync pulse 1 occurs at the proper instant to initiate a cycle as in Figure 10A. Due to the shorter interval T_N, the following free-running cycle will start before the next sync pulse arrives and thus sync pulse 2, Figure 10B, cannot reduce the negative grid voltage below cutoff. Due to their lower frequency, the synchronizing pulses occur later and later in the free-running cycles as shown by numbers 3 and 4, but their amplitude is not high enough to initiate a cycle.

Finally, pulse number 5 is able to start a cycle, but time T_1, between it and the start of the preceding cycle, is shorter than the natural period T_N of the unsynchronized oscillations. Again the oscillation runs free for several cycles, and although not shown in the Figure, the oscillator would be tripped by the ninth synchronizing pulse.

Hence, the blocking oscillator must be adjusted to a frequency slightly lower than the desired oscillating frequency in order that the synchronizing pulses will provide the constant control shown in Figure 10A. Also, the polarity of the applied synchronizing pulses must make the grid swing positive so that the negative bias is reduced and plate current is allowed to start. Proper triggering action does not occur if negative pulses are applied to the blocking oscillator grid.

THE MULTIVIBRATOR

The type of pulse generator known as the **multivibrator** does not require inductive or transformer coupling, but instead depends for its operation upon a system of positive feedback obtained by RC circuits.

Because of its large number of applications, the multivibrator has many variations, but as the general principles of operation are alike, the following explanations of the action in the basic circuit will aid in the understanding of any particular modification which may be encountered.

This basic circuit is practically the same as that of a resistance coupled amplifier, and the method by which the signal is coupled from one stage to the next comprises one of the main principles of the oscillator operation. For this reason, the coupling action will be reviewed briefly before the multivibrator actions are described.

In a two stage resistance coupled amplifier with a circuit like that of Figure 11, the input signal voltage E_I appears across resistor R_1 and is applied to control grid G_1 of tube V_1. Amplified by the tube, the signal reappears with greater magnitude across plate load resistor R_{L_1}. Coupled by C_1 and R_2, the amplified signal is impressed on control grid G_2 of tube V_2. Here the signal is amplified by tube V_2 and reappears with still greater magnitude as the output voltage E_o across plate load resistor R_{L_2}. Bypassed by capacitors C_{K_1} and C_{K_2}, resistors R_{K_1} and R_{K_2} provide the necessary grid bias.

To follow the action in detail, first consider only the part of the E_I input voltage cycle that swings grid G_1 positive. This positive swing increases the plate current in V_1. With a constant B+ supply, the increased voltage across R_{L_1} reduces the positive voltage on plate P_1.

As shown by the partial circuit of Figure 12, in which resistor R_{L_1} is omitted, the V_1 plate voltage E_{P_1} is applied across C_1 and R_2 in series. Thus, with d-c plate voltage, but no signal, C_1 is charged to the voltage of P_1 so that $E_{C_1} = E_{P_1}$. When the signal swings the grid of V_1 positive, the increase in plate current decreases the plate voltage, and C_1 discharges to a lower voltage.

In order for C_1 to discharge, electrons must leave its lower "−" plate, and be added to the upper "+" plate. The path of this electron movement is from the lower plate, down through R_2 to ground and up through R_{K_1} and V_1 to the upper plate. The direction of this electron flow develops a voltage across R_2 such that the upper end of this resistor becomes negative with respect to ground.

Voltage of E_{R_2} makes the grid of V_2 more negative since, as shown in Figure 11, G_2 is connected to the ungrounded end of R_2. The negative swing of G_2 decreases the plate current of V_2, and thus reduces the voltage across the load resistor R_{L_2}. With less voltage across R_{L_2}, the V_2 plate voltage rises to cause a positive swing of the output signal E_o. Thus, insofar as phase relations are concerned, a positive swing of E_o is caused by a positive swing of the input signal E_I.

Consider now the portion of the E_I input voltage cycle that swings G_1 negative. The V_1 plate current is reduced, the voltage across R_{L_1} decreases and the plate voltage E_{P_1} rises. Referring to Figure 12, for C_1 to charge to a higher E_{P_1}, electrons must flow from ground up through R_2 to the bottom plate of C_1. This movement causes the upper end of R_2 to be positive with respect to ground, and this positive signal applied to the grid of V_2, Figure 11, increases the V_2 plate current. The increased voltage across R_{L_2} makes plate voltage E_{P_2} or E_o less positive, that is, it swings in a negative direction.

Thus, the charge and discharge action of the capacitor in the C_1R_2 circuit causes the signal to be coupled from the plate circuit of V_1 to the grid circuit of V_2. An important point, here, is that the charge on C_1, Figure 12, does not change polarity at any time, but the voltage across it alternately increases and decreases with the charge and discharge. A second important point is that a positive swing of the grid of either tube results in a negative swing of the plate of the same tube, while a negative grid swing results in a positive plate swing.

The Basic Multivibrator Circuit

Except for some rearrangement of the diagram, the multivibrator circuit of Figure 13 is basically the two stage amplifier of Figure 11. The only changes are the omission of the cathode circuit components and addition of capacitor C_2 to couple the plate of V_2 to the grid of V_1.

Slight variations in the emission properties of the cathodes, the plate resistances of the tubes as well as circuit components cause changes or differences of current and voltage to occur quite readily so that any practical multivibrator begins to oscillate the instant the supply voltage is applied. Therefore, for the following explanations, assume the circuit is in operation and the discharge currents of the coupling capacitors alternately drive the tube grids negative beyond plate current cutoff.

During one part of the oscillatory cycle, tube V_1 is held cut off while V_2 conducts. This temporarily stable state exists until the negative bias on the V_1 grid reduces sufficiently to allow plate current. The V_1 plate current produces a voltage across R_3, thereby reducing the voltage at the plate of V_1.

Generated by the sweep circuits, the deflection currents are carried in the vertical and horizontal coils of a yoke like that shown here to provide the scanning motion of the spot on the screen.

Courtesy Standard Electronic Division Hupp Corp.

With reduced V_1 plate voltage, capacitor C_1 discharges through resistor R_2 and the resulting voltage E_{R_2} drives the grid of V_2 negative with respect to its cathode. With a negative grid, the plate current of V_2 is reduced, and the resultant rise of plate voltage causes C_2 to charge through resistor R_1 and impress a positive voltage on the grid of tube V_1. The positive grid greatly increases the plate current of V_1, causing its plate voltage to drop lower, and permit a further discharge of C_1. Carried by resistor R_2, this discharge current causes the grid of V_2 to become sufficiently negative to hold the tube at cutoff for a period of time while C_1 is discharging.

By the time the discharge of C_1 is nearly completed, the voltage across R_2 has decreased to slightly less than cutoff, and V_2 becomes conductive. The V_2 plate current produces a voltage across R_4, thus causing the V_2 plate voltage to decrease. This condition permits C_2 to discharge through R_1, making the grid of V_1 negative with respect to its cathode.

With a negative grid, the V_1 plate current is reduced and the resulting increase of plate voltage causes C_1 to charge through R_2, thereby impressing a positive voltage on the grid of V_2. With a positive grid, the V_2 plate current increases to a comparatively high value, and the corresponding decrease of plate voltage permits sufficient discharge of C_2 through R_1 to bias V_1 to cutoff.

This condition continues until C_2 is almost discharged and the voltage across R_1 has reduced until slightly less than cutoff to permit V_1 to become conductive and begin the next cycle. Thus, the entire action repeats itself continually, with V_2 conducting when V_1 is cut off, and V_1 conducting when V_2 is cut off.

However, the V_1 grid and plate voltages are 180° out of phase with the V_2 grid and plate voltages, respectively. The grid or plate voltage of either tube may be taken as the output of the circuit.

The portion of each cycle that V_1 is cut off depends upon the time constant R_1C_2, and the cutoff time of V_2 depends upon the time constant R_2C_1. In the circuit of Figure 13, when $V_1=V_2$, $C_1=C_2$, $R_1=R_2$, and $R_3=R_4$, the grid voltages have the wave-form shown in Figure 14A, and the plate voltages have the wave-form of Figure 14B.

Here, the dashed line co indicates the cutoff level of grid voltage E_c. Curves A and B represent the grid and plate voltages of the same tube, either V_1 or V_2. For example, when the grid voltage of V_1 is more negative than cutoff, plate current is zero, and the plate voltage of this tube is highly positive. The vertical dashed lines numbered 1 and 2 indicate this period. When the grid is more positive than cutoff, the tube conducts, and the plate voltage is low as indicated between dashed lines

2 and 3. With $R_2C_1=R_1C_2$, V_1 and V_2 have equal cutoff times, and equal conduction times. Therefore, as mentioned, curves A and B apply to V_2 also.

Because of the symmetry of components and connections used, this circuit output has positive and negative pulses of equal duration. Therefore, it is called a symmetrical multivibrator. By employing unequal components, narrow or wide output pulses may be produced as desired. In this case the circuit is called an asymmetrical multivibrator, and is the type employed in television receiver sweep circuits.

Figure 13 shows the output taken from the plate of V_2. To obtain a wave-form equivalent to that of Figure 5A, the plate of V_2 should be highly positive for a short interval, compared with the time that its voltage is low. Since the plate voltage E_b swings positive when the tube is cut off, the cutoff time of V_2 should be short compared with the cutoff time of V_1. This operation is accomplished by choosing components such that the time constant R_2C_1 is short compared with R_1C_2. The grid voltage of V_2 then has the wave-form shown in Figure 15A. As the cutoff interval between points 1 and 2 is short, the plate voltage of this tube has the desired form shown in Figure 15B.

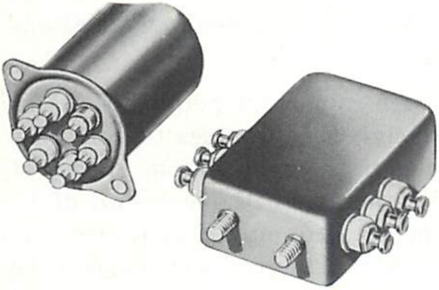
The Cathode Coupled Multivibrator

Another form of multivibrator circuit, shown in the diagram of Figure 16, includes a dual triode tube V_1V_2, although separate tubes may be employed. Here, the plate of V_1 is coupled to the grid of V_2 by means of capacitor C_1, but there is no capacitive coupling between the V_2 plate and V_1 grid. The necessary feedback from V_2 to V_1 is obtained by means of the unbypassed, common cathode resistor R_2, which carries both plate currents, any changes of which result in corresponding variations in the bias E_{R_2}.

An important point is that, although E_{R_2} provides the only d-c bias in the grid-cathode circuit of V_1, the grid-cathode circuit of V_2 includes not only R_2, but also variable resistor R_3 which carries the charge and discharge currents of capacitor C_1. Thus, the total bias on the grid of V_2 is equal to the sum of the voltages across R_3 and R_2.

To understand the oscillator action, assume that, after coming out of cutoff, tube V_1 starts to conduct. The resulting voltage across R_6 decreases the V_1 plate voltage and C_1 discharges through R_3. This electron flow from the negative plate of C_1 to ground makes the upper end of R_3 sufficiently negative to drive the grid of V_2 to cutoff.

When the discharge of C_1 is nearly complete, the voltage across R_3 is low enough to permit the grid to rise above the cutoff voltage and initiate plate current in V_2. The resulting increase of current in R_2 tends to make both grids negative and reduce both plate currents. The decrease in V_1 plate current results in less voltage across R_6 and R_2. The plate voltage rises and C_1 now charges through R_3, causing a positive voltage to be impressed on the grid of V_2.



Called "pulse transformers", these units have various circuit applications among which are the blocking oscillators employed in television receivers.

Courtesy Chicago Standard Transformer Corp.

The resulting heavy conduction of V_2 increases the voltage across R_2 sufficiently to cut off V_1, but cannot cut off V_2 because the total bias voltage between its grid and cathode is positive. This is due to the fact that the positive voltage across R_3 is greater than the negative bias voltage across R_2 to make the net voltage $(E_{R_3}-E_{R_2})$ positive. But, as mentioned earlier, the voltage across R_2 is the only bias applied to V_1, and consequently cuts this tube off.

When capacitor C_1 is charged almost to the voltage of the V_1 plate, the charging current is reduced, thereby reducing the voltage across R_3, and the V_2 positive grid voltage. The V_2 plate current is reduced, resulting in less bias across R_2. Finally, E_{R_2} is too small to maintain cutoff, therefore V_1 conducts to begin a new cycle.

Frequency Control

Multivibrators oscillate at some exact frequency only when a controlling voltage or sync pulse is applied to the grid of either tube. For example, a control voltage input signal may be applied across grid resistor R_1, as indicated in Figure 16. As with the blocking oscillator, positive control or sync pulses will control the multivibrator if they are timed to arrive just before the tube (V_1 in this case) begins conduction due to the natural circuit action. However, if they have sufficient amplitude, negative pulses may be employed to drive to cutoff the tube to which they are applied. One advantage in the use of such negative sync pulses is that the circuit cannot be triggered by signals with magnitudes less than the sync pulses.

SINE-WAVE OSCILLATOR

The sine-wave type sweep oscillators employ pulse generating circuits in which oscillations are produced in the same manner as in the a-f and r-f oscillators described in earlier lessons. One of these LC types, used in television receiver sweep circuits, is the electron-coupled oscillator of Figure 17. Here, transformer T_1 and other circuit components are connected to the cathode, control grid, and screen grid of tube V_1 to form a Hartley oscillator circuit. The screen grid of the tube serves as the anode of the oscillator, to which the plate is coupled by means of the varying electron stream.

The lower section of transformer T_1 carries the oscillator anode (screen) current in addition to the plate current. Thus, the complete anode circuit may be traced from the cathode through tube V_1 to the screen grid, through R_3 to B+, through the power supply to ground, and from ground through the lower section of transformer T_1 to the cathode. Resistors R_1 and R_2 and capacitor C_1 develop grid leak bias for the control grid. With a small t/T ratio, C_2R_3 maintains a constant screen voltage, and R_4 serves as the plate load resistor.

Changes in screen (anode) current in the lower part of T_1 result in moving flux lines which induce a voltage in the upper part of T_1. This voltage is coupled by C_1 to the control grid of V_1. Thus, as with the blocking oscillator, when V_1 begins to conduct, the increasing current in T_1 causes a positive voltage to be applied to the grid. The positive grid increases anode current further, and this action continues to anode current saturation.

With no further increase of anode current, the induced grid voltage dies out, and C_1 begins to discharge through R_1, making the grid negative. The negative grid decreases the screen current, and the changing flux lines now induce a negative voltage across the upper part of T_1. This voltage drives the control grid negative to cutoff. At this point, since there can be no further decrease of screen current, the induced negative voltage dies out, permitting tube V_1 to conduct and start another cycle.

The oscillation frequency is determined primarily by the inductance and distributed capacitance of transformer T_1. To obtain a lower frequency a capacitor is connected across the winding of transformer T_1. In contrast to the blocking oscillator, the grid circuit RC time constant is not sufficient to cause the oscillator to block. Therefore, the positive and negative alternations of grid voltage are of about equal duration.

When the circuit of Figure 17 is operating normally, the control grid sine-wave voltage variations are sufficient to drive the tube between saturation and cutoff, as explained. Because the grid voltage swings negative beyond cutoff, and positive beyond saturation, the plate current cannot follow the variations during the grid voltage peaks. Thus, the tube operates as an overdriven amplifier. The resultant clipping action produces a voltage across R_4 which has the wave-form shown in Figure 18A. When applied to the short time-constant high pass circuit C_3R_5, the output consists of narrowed pulses as shown in Figure 18B.

PRODUCING SAWTOOTH CURRENT

If the magnetic deflection coil circuit consisted of resistance only, a sawtooth current could be produced in it simply by applying a sawtooth voltage. This is illustrated in Figure 19A, where, applied to resistor R, sawtooth voltage e_a results in current I_R having sawtooth wave-form. However, due to the inductance of the deflection coils, an applied sawtooth voltage does not cause a sawtooth current. If the magnetic deflection coil circuit consisted of inductance only, with no resistance, a sawtooth current I_L could be produced by applying a rectangular voltage as shown in Figure 19B.

However, in a practical magnetic deflection circuit, the coil inductance L and resistance R_L are effectively in series with the amplifier tube plate resistance R_p as shown in the simplified circuit of Figure 19C. Therefore, as the circuit contains both resistance and inductance, neither a sawtooth nor a square wave of applied voltage will produce sawtooth current. To provide sawtooth current in a circuit of this type, the impressed voltage must have a trapezoidal wave-form. That is, it must have both square and sawtooth components, as shown by voltage e_a of Figure 19C.

One method of producing a trapezoidal voltage is illustrated in Figure 20A, where tube V_1 represents the discharge tube of the deflection voltage generator, and R_1 the high resistance through which sawtooth-forming capacitor C_1 charges. A second resistor, R_2, is connected in series with capacitor C_1 so that both the charge and discharge currents of C_1 are carried by it. Since the resistance is relatively small, it has little effect on the charging and discharging rates of the capacitor.

When V_1 is cut off and C_1 is charging, electrons flow from ground through R_2 to the negative plate of C_1, and from the positive plate through R_1 to B+. When V_1 conducts, electrons leave the negative plate of C_1, flow through R_2 to ground, and from ground through V_1 to the positive plate of C_1. This flow develops a sawtooth voltage e_c across C_1, as indicated in Figure 20B.

The charge and discharge currents of C_1 are carried by R_2, and thus develop a voltage e_{R_2} with the wave-form shown in Figure 20B. Referring to Figure 20A, when C_1 is charging, the direction of electron flow is such that the upper end of R_2 is positive with respect to ground. When C_1 is discharging, the electron flow makes the upper end of R_2 negative with respect to ground.

At the beginning of the cycle, the charging current is maximum and e_{R_2} has a maximum positive value as shown in Figure 20B. As C_1 charges, the current decreases and e_{R_2} falls toward zero. At the beginning of the discharge interval, the discharge current has a high value and a high negative voltage is produced across R_2, but as the discharge current dies down, the negative value of e_{R_2} is reduced. The instant V_1 stops conducting, C_1 again begins to charge and the polarity of e_{R_2} becomes maximum positive immediately, thus completing the cycle.

As indicated in Figure 20A, the output voltage e_o is developed across C_1 and R_2 in series. Therefore, at every instant, e_o is equal to the sum of e_C and e_{R_2}. This addition is shown graphically in Figure 20B where the addition of the e_C and e_{R_2} provides the trapezoidal wave-form e_o. When used for this purpose, R_2 of Figure 20A is called a **peaking resistor.**

The 17-inch picture tube fills the entire front of this receiver designed to fit the motif of the game room or den.

Courtesy Raytheon Mfg. Co.—
TV and Radio Operations

SWEEP OSCILLATOR CIRCUITS

As we have explained, the complete sweep oscillator includes a pulse generator, a discharge tube, and a voltage shaping RC circuit. These three units are indicated by the blocks in the diagram of Figure 21. Also, as mentioned, when the pulse generator is a multivibrator, one of the multivibrator tubes serves as the discharge tube. In the case of the blocking oscillator, the pulse output, Figure 6B, is applied to the grid of a separate discharge tube, or the blocking oscillator tube itself serves also as the discharge tube. Either of these latter arrangements are employed also when the pulse generator is of the sine-wave type. The third block in Figure 21 includes the sawtooth forming capacitor and peaking resistor. This trapezoidal voltage shaping circuit usually is connected from ground to the plate of the discharge tube, as in Figure 20A.

Vertical Oscillators

For the vertical sweep circuit, an oscillator is needed which can be synchronized easily by means of the sync pulses. Whenever the receiver is switched to a different channel, or there is a station break in a network broadcast, the newly received sync pulses do not correspond to the starting times of the sweep oscillator cycles. This fact makes it necessary for the vertical oscillator to quickly change its starting time until it is in step with the new sync signals. An extremely stable oscillator is not desirable for this application, for such a circuit would not follow the rapid changes of phase of the sync pulses. Thus, to provide speed and accuracy of synchronization, the vertical oscillator is a relatively "unstable" circuit which, under the control of the sync pulses, can be made to change phase by a large amount from one cycle to the next.

Both the multivibrators and the blocking oscillators are circuits of this type. In each case, a cycle can be interrupted and a new one begun the instant a large enough pulse is applied to the sync input grid. The amplitude of the sync pulse required depends upon the part of the cycle in which it arrives, the tube characteristics, circuit values, and operating voltages. The sine-wave type sweep oscillator cannot be shifted in phase rapidly by the sync pulses, and therefore is much too stable for use in the vertical deflection circuits.

The integrating circuit, which separates the vertical sync pulses from the horizontal, also eliminates most of any noise pulses that happen to pass through the sync circuits. Because of this action, the vertical oscillator is not greatly affected by noise, even though the blocking and multivibrator oscillator types are easily controlled by pulses applied to their sync input grids.

Figure 22 illustrates a typical commercial vertical sweep oscillator. This circuit is employed in the Raytheon Model UC-2403A television receiver. The single triode V_1 and associated components serve as a blocking oscillator type pulse generator and discharge tube circuit. As explained for Figure 6A, in the circuit of Figure 22, transformer primary L_1 couples energy from the plate circuit to secondary L_2 in the grid circuit. When plate current is rising, the current in L_1 produces an expanding magnetic field which cuts L_2 to induce a voltage which makes the grid positive. The positive grid increases plate current until it approaches saturation.

Here, the plate current rises at a reduced rate, the field about L_1 expands more slowly and cuts the turns of L_2 less rapidly. With reduced induction, the voltage across L_2 falls, making the grid less positive. Plate current decreases, and the magnetic field begins to collapse, inducing a negative voltage across L_2. The negative grid quickly reduces the plate current to a low value. As a result, the field collapses rapidly to induce a large negative voltage across L_2 which drives the grid negative far beyond plate current cutoff.

With no plate current, there is no magnetic field, and the voltage across L_2 falls to zero. However, V_1 is now held cut off by the voltage E_{C_1}, since capacitor C_1 was charged by grid current during the interval the grid was positive. With its negative terminal toward the grid, C_1 acts as a bias source in the circuit consisting of the grid, L_2, C_1, the sync source, and the cathode. As the charge on C_1 leaks off through R_1, E_{C_1} slowly decreases, and would finally be too small to cut off the tube. Just before this point, however, a positive sync pulse arrives to drive the grid in the positive direction, thus producing plate current and starting a new cycle.

During the time that V_1 is cut off, capacitor C_2 charges through R_4 and R_2. When V_1 conducts a short pulse of plate current, C_2 is partly discharged by electron flow from its lower plate, down through R_4 to ground, to the cathode of V_1, and through the tube and L_1 to the upper plate of C_2. When conductive, V_1 has much lower resistance than R_2. Also, the peaking resistance R_4 is much smaller than R_2. Thus, R_2 (plus R_4) is the high resistance through which C_2 charges slowly, while the V_1 plate resistance (plus R_4) is the low resistance through which C_2 discharges quickly. The charge and discharge currents produce a voltage across R_4 which, added to the sawtooth voltage E_{C_2}, provides the desired trapezoidal voltage as indicated at the output terminals.

Instead of being connected to ground, the lower end of R_1 is connected to the slider on potentiometer R_3. This arrangement stabilizes the oscillator frequency. Resistors R_2 and R_3 form a voltage divider from B+ to ground. Thus, from the slider on R_3, a small positive voltage is applied in series opposition to the negative voltage E_{R_1}, produced by the discharge of C_1. At any instant while V_1 is cut-off, the net grid bias is equal to E_{R_1} less the positive voltage across the lower portion of R_3. The free-running frequency of the blocking oscillator is selected by adjusting the slider on R_3 for the desired net bias.

SWEEP OSCILLATOR TUBE TYPES

VERTICAL	HORIZONTAL
6AV6	6AU7
6BF6	6CG7
6C4	6SN7
6CG7	12AU7
6SN7	12AT7
12AU7	—
12BH7	—
12AX7	—

These tube types are commonly employed as sweep oscillators in television receivers. Often, only one section of the double triode types serves as the oscillator.

Undesired changes in the B+ supply voltage can change the bias of a blocking oscillator, and thus change the frequency. For example, if the B+ voltage increases, it raises the plate voltage of V_1, causing the plate current pulses to have greater amplitude. Supplied through the transformer to the grid circuit, the greater feedback energy increases the developed grid leak bias voltage. A higher negative bias decreases the oscillation frequency.

However, with the stabilizing circuit arrangement of Figure 22, the current carried by R_2 and R_3 increases also when the B+ voltage rises. The increased divider current produces larger voltages across these resistors. The larger positive voltage across the lower portion of R_3 counterbalances the increased grid leak bias to maintain a constant net bias on the grid of V_1. Therefore, the oscillator frequency remains constant. Likewise, any decrease in the B+ voltage results in a decrease in both E_{R_1} and R_{R_3}, and again the net bias and oscillator frequency remain unchanged.

Another form of blocking oscillator type sweep oscillator is shown in Figure 23. This circuit is like that in the Motorola Chassis TS-525 receiver, and is one of the most commonly used forms. Again, a single triode serves as both pulse generator and discharge tube. Compared to those circuits already explained, the most important difference, here, is that the transformer primary L_1 is located in the cathode circuit. As the cathode circuit carries the plate current, the pulses of plate current through L_1 couple energy to the grid circuit to produce the oscillator action. Grid current charges C_1 so that its upper plate is negative, and the overall action provides the desired grid bias. While V_1 is cut off, C_1 discharges through R_1 to slowly reduce the grid bias. Also, during this time, C_3 charges through R_2 and R_3. The pulse of plate current discharges C_3 so that a trapezoidal voltage wave-form is produced across C_3 and R_3.

Called the **hold control,** R_1 determines the rate at which the charge leaks off of C_1, and therefore the free-running frequency of the oscillator. Variable resistor R_2 controls the charging time-constant of C_3, and therefore the voltage to which C_3 can charge during the period that V_1 is cut off. As this voltage determines the amplitude of the sweep oscillator output, and therefore the amplitude of the sawtooth current in the vertical coils of the deflection yoke, variable resistor R_2 is called the **height control.** The half-cycle of oscillation of the grid voltage is given the desired duration by tuning L_1 with the parallel capacitor C_2.

The Craftsmen Model C210 television receiver employs the vertical sweep circuit of Figure 24. The circuit of tube V_1 is a blocking oscillator, and includes transformer T_1, capacitors C_1, C_2 and C_3, and resistors R_1, R_2, R_3, and R_4. As in the circuit of Figure 23, the primary of T_1 is in the cathode circuit of V_1, Figure 24. The voltage wave-form at the grid is indicated in the Figure. The brief positive pulses of this voltage cause grid current which charges C_1, thus providing the negative bias which holds V_1 cut off. Between pulses, the C_1 charge leaks off through R_1 and R_2.

R_2 is the vertical hold control, since its setting determines how fast C_1 discharges to reduce the bias to the point where V_1 can begin conduction. At low values of R_2, the discharge time is short, and the oscillator frequency high. Conversely, the frequency is lowered when the R_2 resistance increases.

Since the grid of V_1 is connected directly to the grid of V_2, the same voltage wave-form is applied to the V_2 grid, as indicated. Thus, V_2 conducts when V_1 conducts, and is cut off when V_1 is cut off. In this circuit, V_2 is the discharge tube. Capacitor C_5 charges through R_7, R_5, and R_6 while V_2 is cut off, and discharges through the tube and R_7 when the positive pulse of the grid voltage causes V_2 to conduct. This action produces the trapezoidal output voltage wave-form. Adjustment of R_6, the height control, determines the voltage to which C_5 charges, and therefore the trapezoidal amplitude produced, during the interval V_2 is cut off.

Figure 25 is an example of a cathode-coupled multivibrator used in the vertical sweep circuit of a Sylvania 596B receiver. Here, triode V_2 serves as the discharge tube, and the trapezoidal voltage wave is produced across C_3 and R_6. R_1 provides bias to the cathodes of both tubes, while C_1 helps to shape the feedback pulse by increasing the rise time. The variations of V_1 plate voltage are coupled by C_2 to the grid of V_2. Variable resistor R_3 is the hold control. The total resistance of R_4 and the used portion of R_3 determine the time required for C_2 to discharge.

At the point in the cycle where V_1 begins to conduct, its plate voltage falls to a value lower than the voltage across C_2. This capacitor begins to discharge through R_3 and R_4. The voltage produced across these resistors makes the grid of V_2 negative with respect to ground, cutting off this tube. With V_2 cut off, C_3 charges through R_5 and R_6.

As C_2 discharges, its discharge current gradually decreases. Eventually, this current would become so small that the voltage across R_3 and R_4 could no longer hold V_2 cut off. However, before this point is reached, a positive sync pulse is applied to the grid of V_2, causing this tube to conduct heavily. This conduction allows C_3 to discharge rapidly through R_6, R_1 and V_2. The large V_2 plate current increases the voltage across R_1, cutting off V_1.

With V_1 cut off, its plate voltage rises toward B+, causing C_2 to begin charging through R_3 and R_4. The resulting voltage across these resistors makes the grid of V_2 positive, thus maintaining heavy conduction in V_2. With the grid of V_2 positive, a second path is provided for C_2 charging current, in parallel with R_3 and R_4. Electrons flow from ground, up through R_1, from cathode to grid in V_2, and into C_2. This path has very low resistance compared with that of R_3 and R_4. Therefore, C_2 becomes charged in a much shorter time than it requires to discharge through R_3 and R_4, when V_2 is cut off.

When C_2 is charged nearly to the plate voltage of V_1, the positive voltage on the V_2 grid is very low. The decreased V_2 plate current can no longer produce a large enough bias across R_1 to hold V_1 cut off. Therefore, V_1 begins to conduct, thus beginning the next cycle. During each cycle, V_2 is cut off for a relatively long interval, and conducts for only a short interval. Since C_3 charges while V_2 is cut off, and discharges when V_2 conducts, the C_3 charge period is much longer than its discharge period. Thus, the unequal rise and fall times of C_3 voltage provide the desired sawtooth wave. As explained previously, the charge and discharge currents produce a voltage waveform across R_6 which, added to the sawtooth voltage of C_3, provides the trapezoidal output voltage indicated.

Figure 26 shows the vertical sweep circuit employed in the Teleking Model K-74 receiver. A common vertical circuit arrangement, the pentode V_2 is the output amplifier, while V_1 and V_2

together operate as a plate-coupled multivibrator. In the plate circuit of V_1, sawtooth forming capacitor C_3 and peaking resistor R_5 form the trapezoidal voltage. Coupled by C_2 and R_6 to the grid of V_2, this voltage is amplified and applied to the primary of output transformer T_1. This transformer couples the plate circuit of V_2 to the vertical coils of the deflection yoke.

To provide the multivibrator action, the plate voltage variations of V_1 are coupled by C_2 to the grid of V_2, and part of the output of V_2 is coupled back to the grid of V_1. However, the voltage at the V_2 plate is the amplified and inverted trapezoid, and therefore not of the proper form to feed back to V_1. To shape the feedback pulse, a wave-shaping network is employed. In the circuit, this network consists of C_5, C_6, R_9, R_{10}, and C_1.

Resistor R_2 is the hold control, as its setting determines the time required for C_1 to discharge through R_1 and R_2. This discharge action maintains V_1 cut off while C_3 charges, and therefore determines the free-running frequency of the oscillator. Resistor R_4 is the height control. R_7, R_8 along with C_4 provide cathode bias for V_2. The C_3 charging current which passes through R_7 and R_8 applies a small signal to the V_2 cathode, 180° out of phase with that on the grid, to cancel distortions. Called the "linearity" control, R_8 permits changing the operating point of the amplifier tube.

The 12BH7 is one of several double triode types used as vertical sweep oscillators. Often, the two triode sections operate as a multivibrator, while one section serves also as the output amplifier.

Courtesy Columbia Broadcasting Co.

Horizontal Oscillators

The horizontal sweep generator must be extremely stable to resist being thrown out of synchronism by noise pulses. The RC circuits designed to reject vertical sync signals and pass horizontal sync signals also pass noise pulses. As explained, noise rejection methods are employed in the sync section of most television receivers. However, these systems usually block only noise pulses which have greater amplitude than the sync pulses.

Extremely stable operation does not hinder the operation of the horizontal oscillator in the way it would the vertical oscillator, so far as phase changing is concerned. The horizontal oscillator completes 262.5 $\left(\frac{15{,}750}{60}\right)$ cycles during the time the vertical oscillator goes through one cycle. Therefore, when the program is switched, the horizontal oscillator can take the time of more than 200 cycles to make the necessary change in phase without being slow in response, visibly, compared with the vertical oscillator.

To increase the stability of the horizontal oscillator, a direct voltage is applied to the grid of the tube. This control voltage increases or decreases the grid bias as needed to correct the oscillator frequency. Described in another lesson, an "automatic frequency control" circuit compares the horizontal oscillator output with the incoming horizontal sync pulses to produce the control voltage with the required amplitude and polarity. Thus, unlike the vertical sync pulses, the horizontal sync pulses are not applied from the sync amplifier directly to the horizontal oscillator. Instead, they are applied to the "phase comparer" which provides the control voltage.

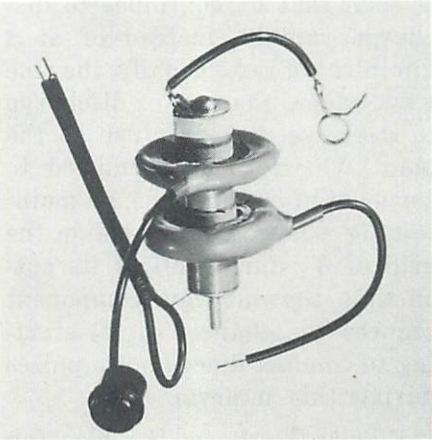
An example of a commercial type horizontal sweep oscillator is given in Figure 27. Here, the pulse generator is a sine wave oscillator. Triode V_1, tank circuit T_1 and C_2, and the grid leak bias components R_1 and C_1 form a Hartley oscillator. The tank is tuned to the horizontal deflection frequency by adjusting the core of T_1. As indicated, the control voltage is applied to the grid circuit of V_1, and is in series with the bias voltage developed across C_1 and R_1.

As with most sine wave oscillators, the tube is biased so that its operating point is negative beyond cutoff. Thus, V_1 conducts for only a small portion of each cycle to replace the energy dissipated in the oscillating tank circuit. These short pulses of plate current are carried by R_2, since this resistor is in the cathode circuit between the lower end of the tank and ground. The plate current pulses produce the indicated voltage wave-form across R_2.

Discharge tube V_2 operates with grid leak bias provided by capacitor C_3 and resistor R_3. The voltage wave taken from across R_2 is differentiated by C_3 and R_3 to form the wave with narrow positive pulses indicated at the grid of V_2. Each positive pulse produces enough grid current to bias the tube negative beyond cutoff for the remainder of the cycle. Thus, V_2 is cut off for a long period and conducts for only a brief interval during each cycle. The indicated trapezoidal voltage is produced across C_4 and R_5, as C_4 charges slowly through R_4 and R_5 while V_2 is cut off, and discharges through R_5 and V_2 when this tube conducts.

The cathode-coupled multivibrator of Figure 28 is employed as the horizontal sweep oscillator in the Craftsmen Model C210 receiver. Except for the difference in circuit values to provide oscillation at the horizontal sweep frequency, this circuit operates in the same manner as explained for the vertical oscillator of Figure 25. In the circuit of Figure 28, the multivibrator action causes tube V_2 to be cut off for a long period and conduct for a short interval during each cycle. With V_2 serving as the discharge tube, the trapezoidal voltage is produced across capacitor C_3 and resistor R_6.

From the output of the automatic frequency control circuit, the control voltage is applied to the grid of tube V_1. If the multivibrator frequency is too high, the control voltage increases the negative bias on the grid to make V_1 remain cut off longer, and thus decreases the frequency. Likewise, when the oscillator frequency is too low, the control voltage decreases the grid bias to allow V_1 to conduct sooner, thus increasing the frequency.



The sweep oscillator is followed by an amplifier stage in each complete deflection circuit. The photo shows one type of transformer employed to couple the output of the horizontal deflection amplifier to the horizontal coils of the picture tube yoke.

Courtesy Merit Coil & Transformer Corp.

Further stabilization of the oscillator frequency is obtained by means of the LC circuit in the V_1 plate circuit. L_1 and C_1 are tuned to resonance at the horizontal sweep frequency. Oscillations are maintained in this tank circuit by the pulses of plate current.

The sine wave voltage generated by this LC circuit is added to the plate voltage of V_1. The combined voltages are applied to C_2 to control its rate of discharge. The phase of the sine wave component is such that C_2 continues to discharge rapidly, instead of at a diminishing rate. Finally, the sine wave causes the rate of discharge to decrease quickly, just at the point where V_2 is permitted to come out of cutoff. Thus, by maintaining a large cutoff bias on the grid of V_2 during all of its cutoff time, the sine wave component reduces the chances of V_2 starting to conduct due to noise pulses during this interval.

Figure 29 shows the blocking oscillator employed as the horizontal sweep generator in the Emerson 120245 Chassis. This circuit basically corresponds to the vertical oscillator circuit of Figure 22. In Figure 29, coils L_1 and L_2 form the primary and secondary, respectively, of the blocking oscillator transformer. Carried by L_1, pulses of plate current produce flux changes which induce a feedback voltage into L_2 to produce oscillations. Capacitor C_1 and resistors R_1 and R_2 provide grid leak bias.

The control voltage is applied across R_2, and therefore aids or opposes the grid leak bias, as required, to correct the oscillation frequency. In this particular chassis, a sawtooth voltage is applied to the horizontal amplifier, as indicated. Therefore, a peaking resistor is not employed in series with the sawtooth forming capacitor C_3. Inserted between L_1 and plate resistor R_4, the tank circuit L_3C_2 stabilizes the oscillator frequency in the manner explained for the circuit of Figure 28. R_3 prevents oscillations at undesired frequencies by damping the tuned circuit formed by L_1 and its distributed capacitance.

As we mentioned at the beginning of this lesson, the various types of sweep oscillators provide voltages with trapezoidal wave-form and the frequencies required for vertical and horizontal deflection of the electron beam in the picture tube. However, the sweep oscillator output level is not high enough to produce the magnitude of sawtooth current required by the deflection coils. Therefore, in addition to the sweep oscillator, the complete deflection circuit includes an amplifier stage. The next lesson describes the requirements and circuits of the output amplifiers employed in the vertical and horizontal sweep circuits.

IMPORTANT DEFINITIONS

BLOCKING OSCILLATOR—A pulse generator in which feed back energy is transformer coupled from the plate or cathode circuit to the grid circuit, and the grid leak bias network provides a long time constant which blocks oscillations for a period between each cycle.

DISCHARGE TUBE—In a sweep circuit, a tube which conducts at the proper intervals to form a low resistance path through which the sawtooth forming capacitor discharges.

HEIGHT CONTROL—Variable resistor which determines the amplitude of the deflection voltage produced by the vertical oscillator, and therefore the vertical dimension or height of the raster on the screen of the picture tube.

HOLD CONTROL—Variable resistor which permits adjustment of the sweep oscillator frequency.

MULTIVIBRATOR—A pulse generator in which feedback energy is resistance coupled, or resistance-capacitance coupled from each to the other of its two tubes.

PEAKING RESISTOR—A resistor in series with the sawtooth forming capacitor in a sweep oscillator circuit. Together, the capacitor and peaking resistor form a trapezoidal voltage.

PULSE GENERATOR—An electron circuit which produces voltage pulses, usually of short duration, at some desired frequency, amplitude and polarity.

SWEEP OSCILLATOR—In a television receiver, an electron tube circuit which provides a voltage of the proper wave-form and frequency to produce the sawtooth current in the vertical or horizontal deflection coils.

STUDENT NOTES

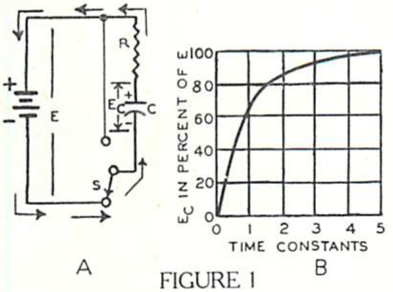


FIGURE 1

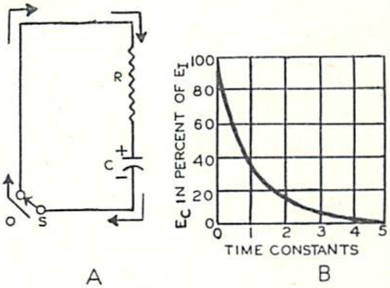


FIGURE 2

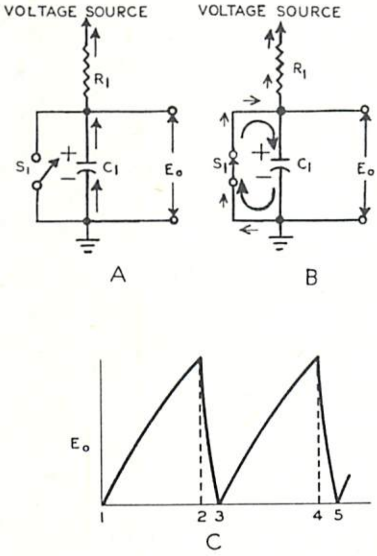


FIGURE 3

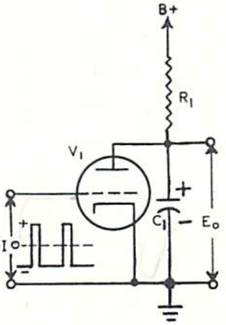


FIGURE 4

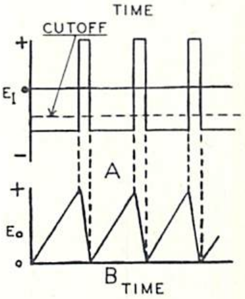


FIGURE 5

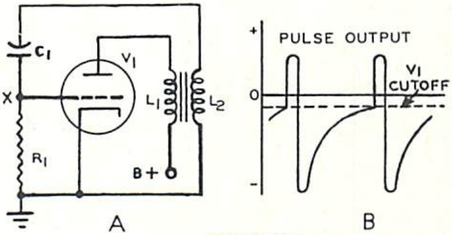


FIGURE 6

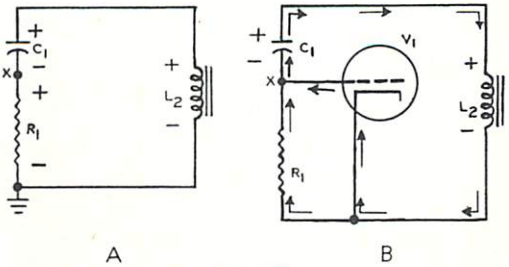


FIGURE 7

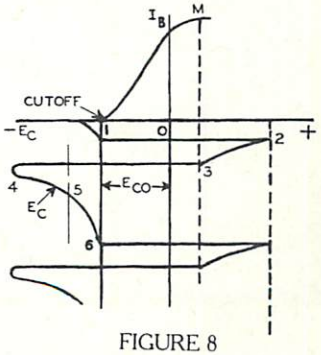


FIGURE 8

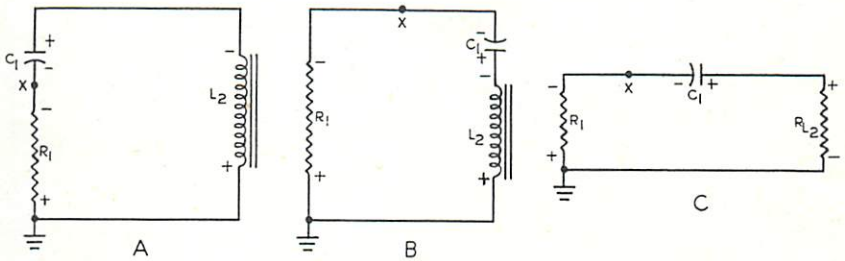


FIGURE 9

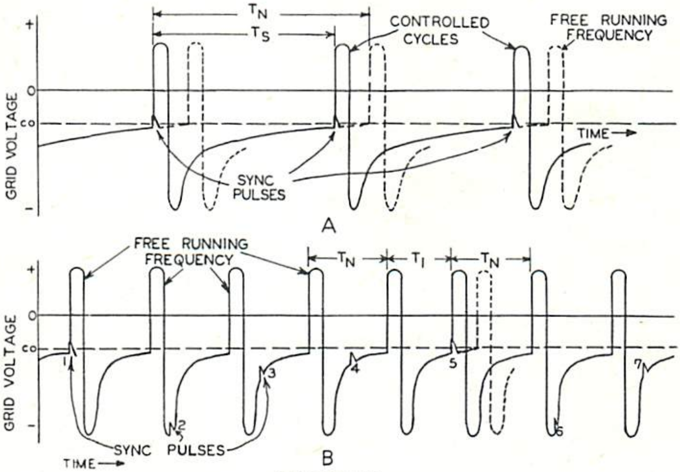


FIGURE 10

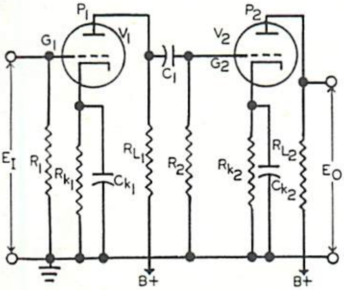


FIGURE 11

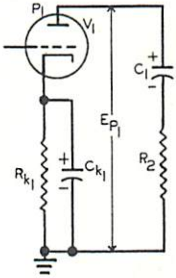


FIGURE 12

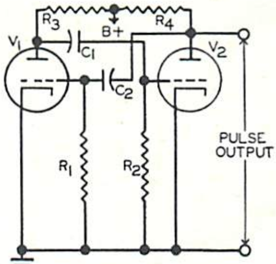


FIGURE 13

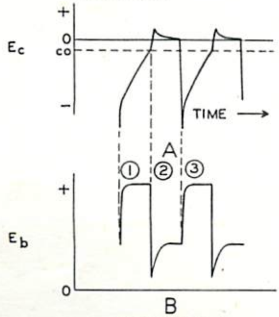


FIGURE 14

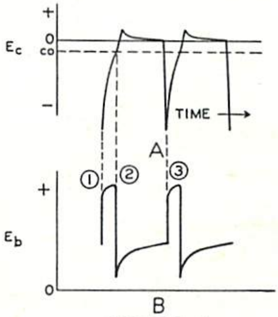


FIGURE 15

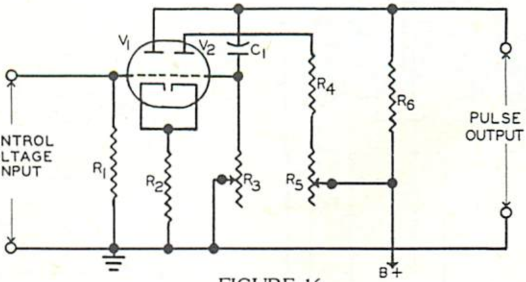


FIGURE 16

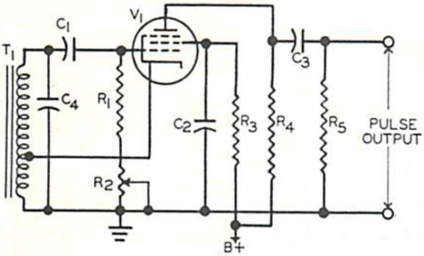


FIGURE 17

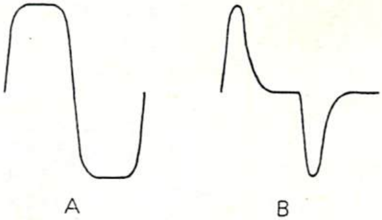


FIGURE 18

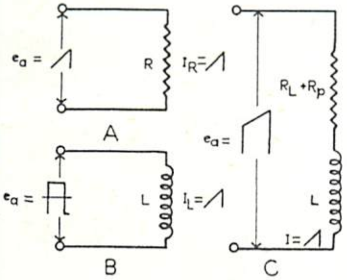


FIGURE 19

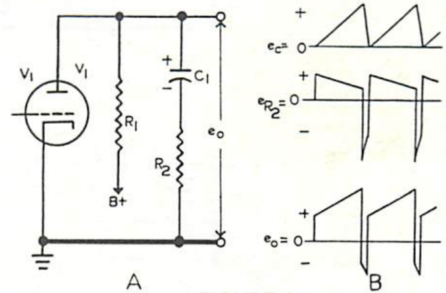


FIGURE 20

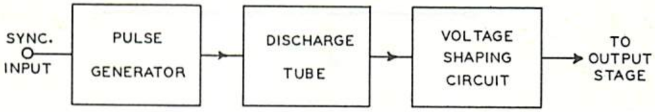


FIGURE 21

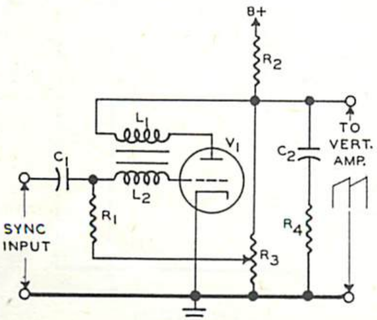


FIGURE 22

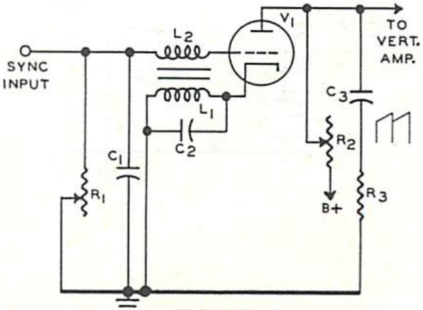


FIGURE 23

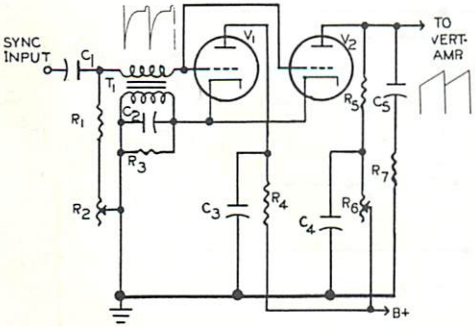


FIGURE 24

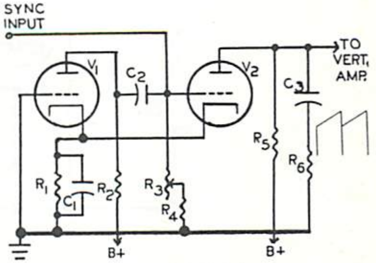


FIGURE 25

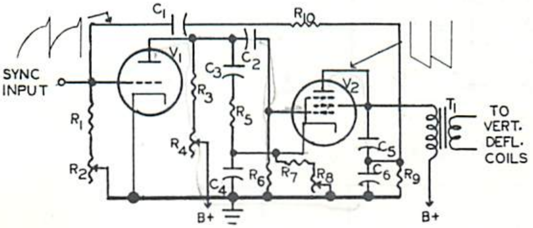


FIGURE 26

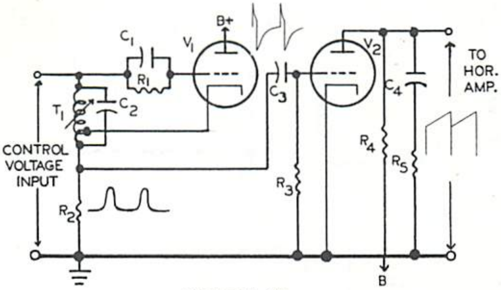


FIGURE 27

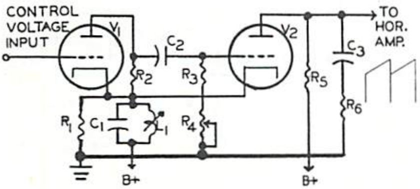


FIGURE 28

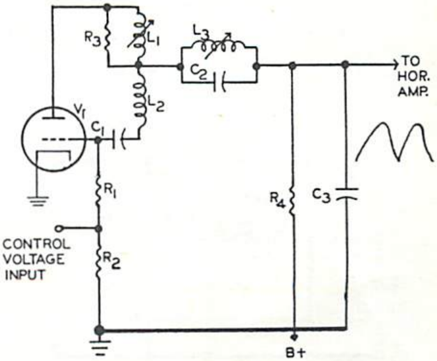


FIGURE 29

FROM OUR *Director's* NOTEBOOK

ANTICIPATING OPPORTUNITY

It might be a good thing if those people who wait so patiently for opportunity to knock at their door would vary their program a little and give a good resounding knock at opportunity's door. This Micawber-like attitude of always waiting for something to turn up has its drawbacks. Time has a habit of slipping away unnoticed, and while these waiters are biding their time at home, others are out and abroad carving their destiny by virtue of their own hands and talents. Like many other proverbs that because of their brevity have been taken to be the soul of truth, the saying that "opportunity knocks once at every man's door" has been abused. Opportunity may come to a man who waits for it, but it is more often found by those who go looking for it.

Yours for success,

W. C. DeVry

DIRECTOR